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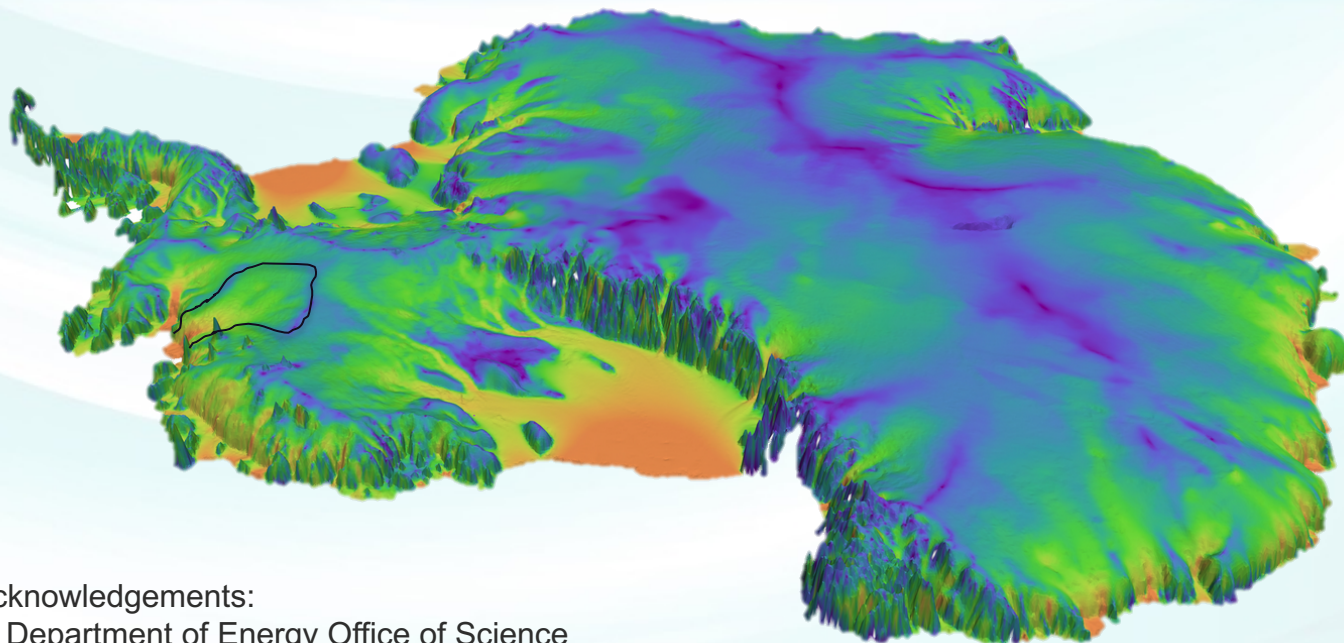
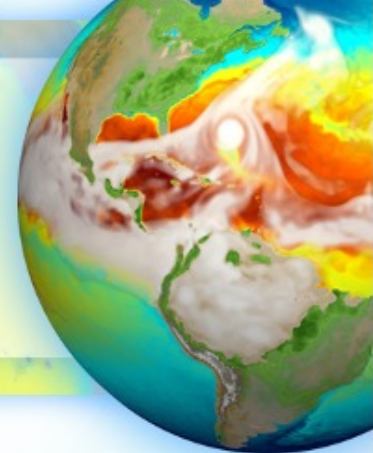
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Mechanisms delaying glacier retreat in the presence of ocean temperature variability at Thwaites Glacier, Antarctica



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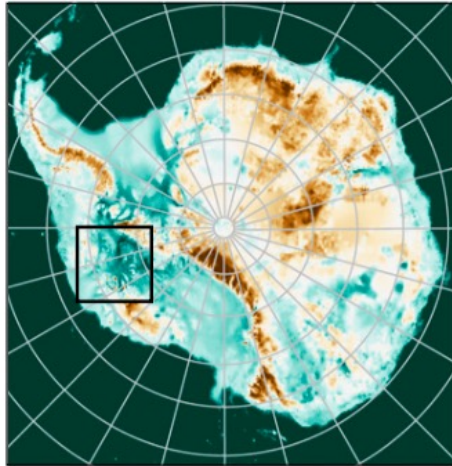
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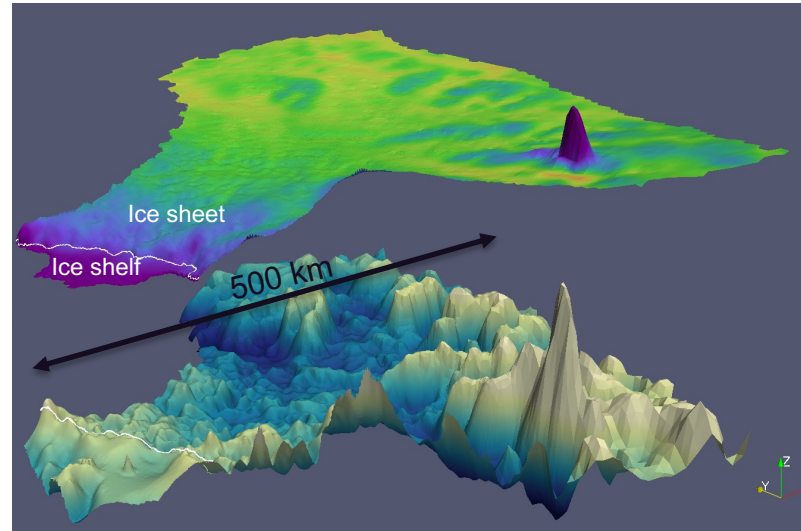
Hoffman, M.J., Asay-Davis, X., Price, S.F., Fyke, J., Perego, M., 2019. Effect of Subshelf Melt Variability on Sea Level Rise Contribution From Thwaites Glacier, Antarctica. *J. Geophys. Res. Earth Surf.* 124, 2798–2822. doi:10.1029/2019JF005155

Thwaites Glacier

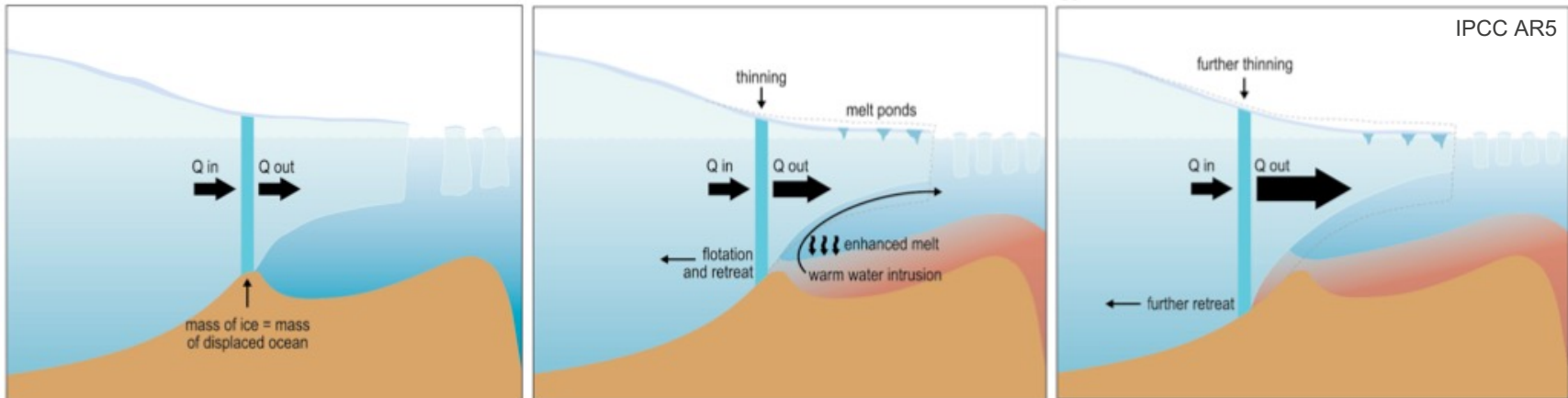
Marine ice sheet with overdeepened basin – 65 cm SLE



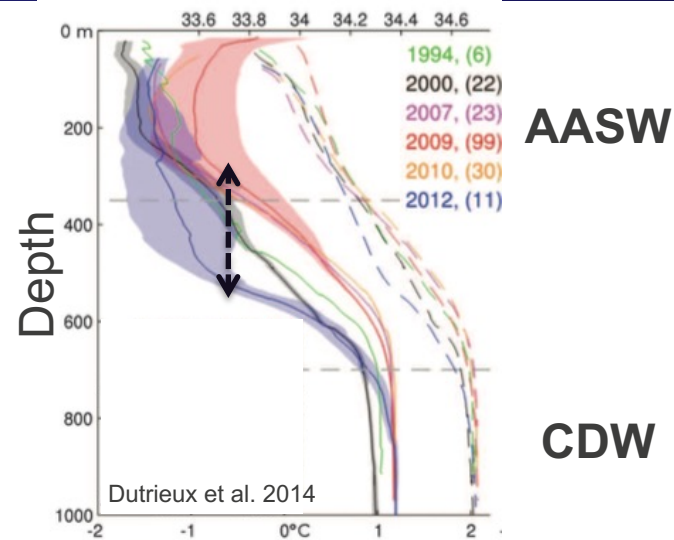
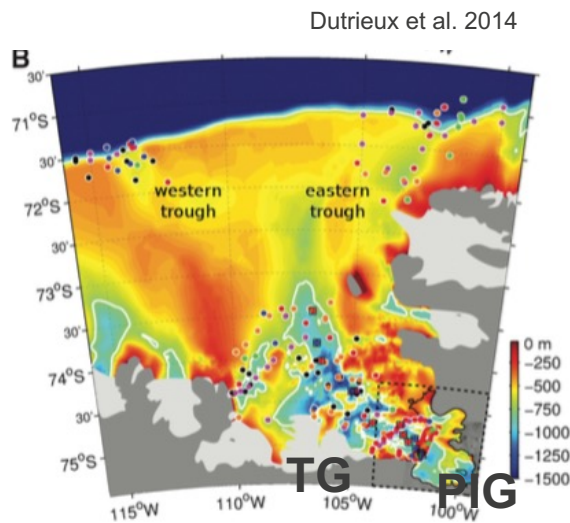
Schroeder et al. 2013



Marine Ice Sheet Instability predicted

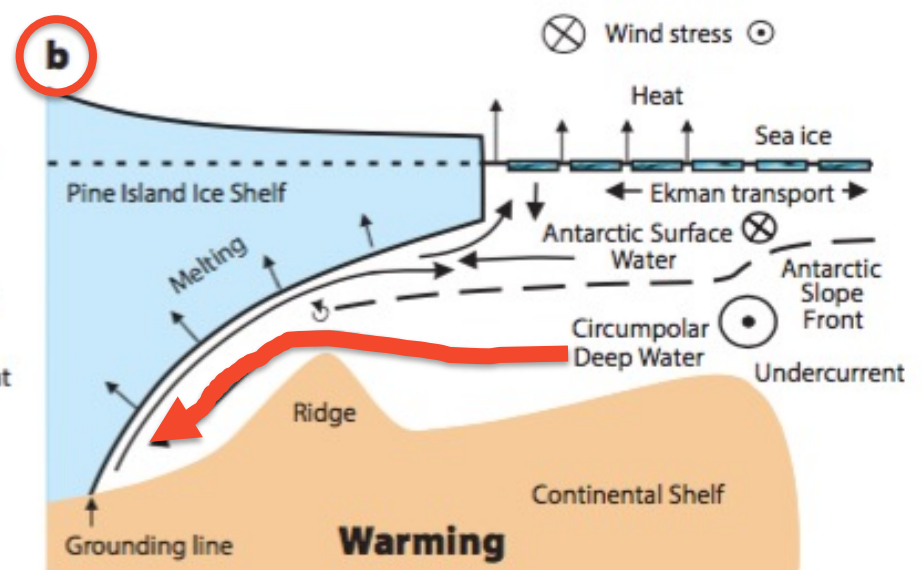
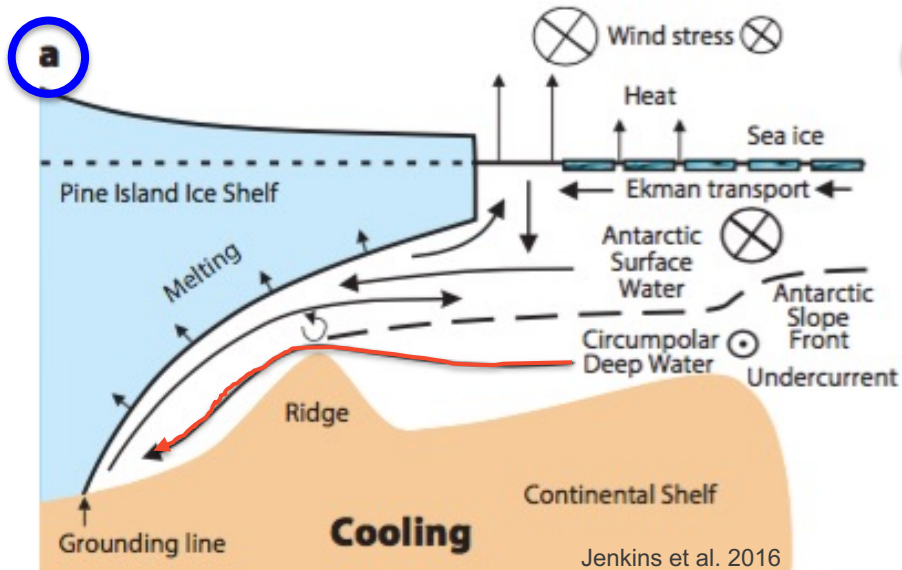
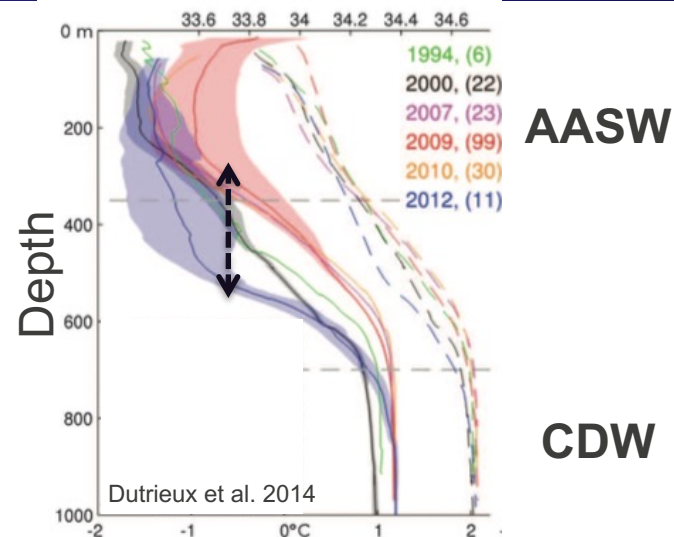
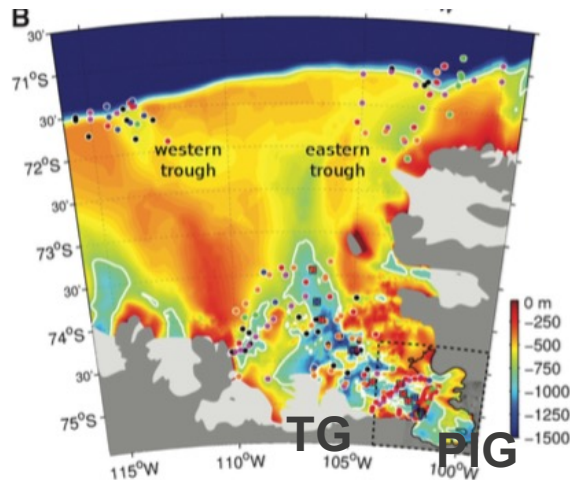


Subshelf melting controlled by access of CDW



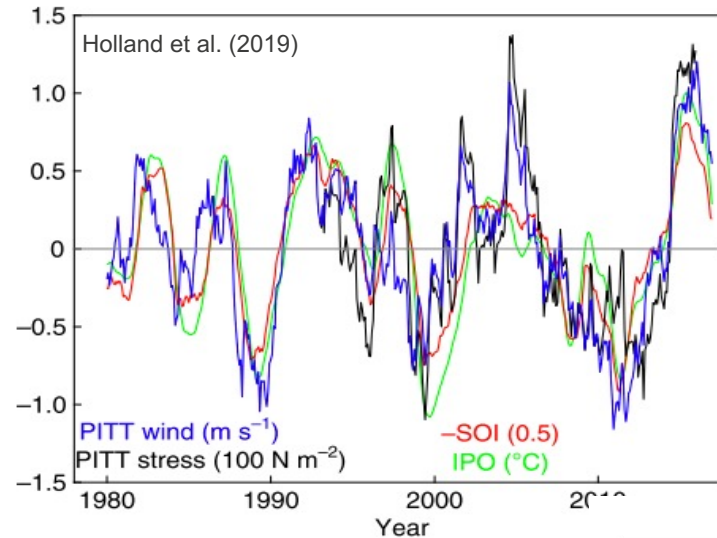
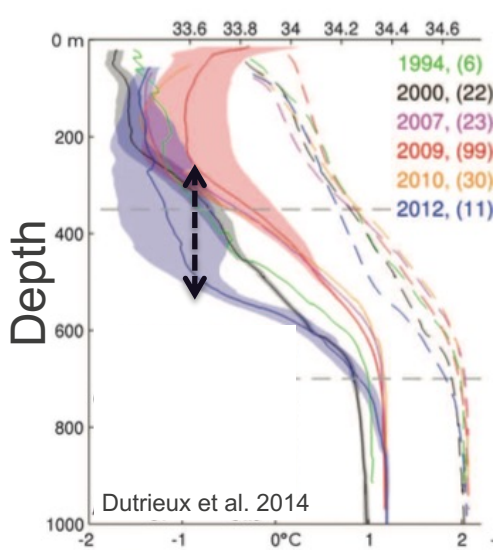
Subshelf melting controlled by access of CDW

Dutrieux et al. 2014

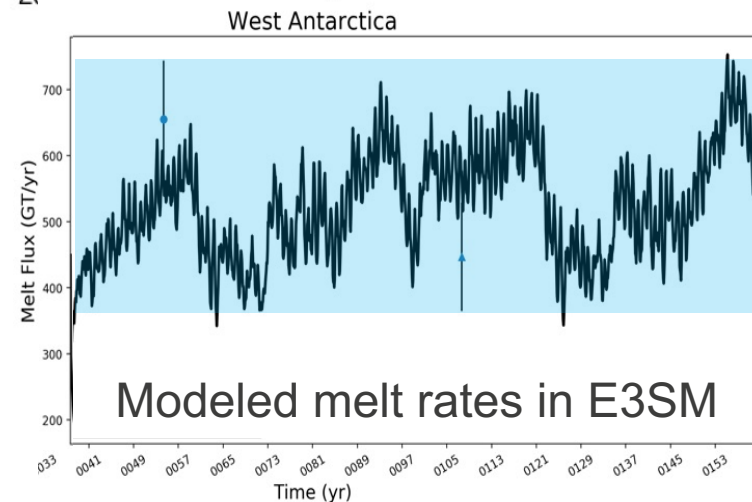


Jenkins et al. 2016

Climate variability affecting Antarctic subshelf melting



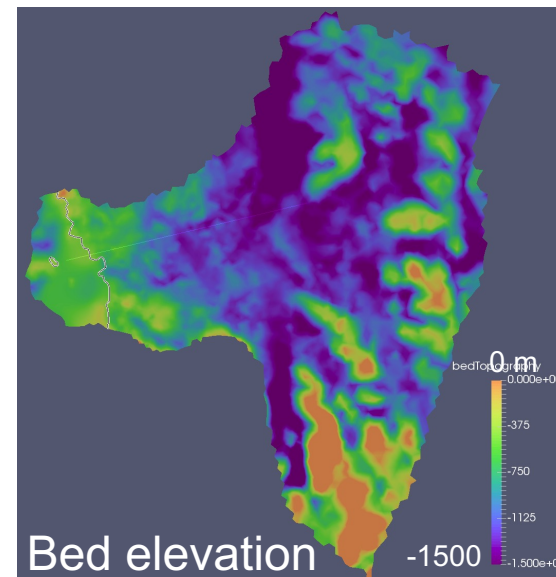
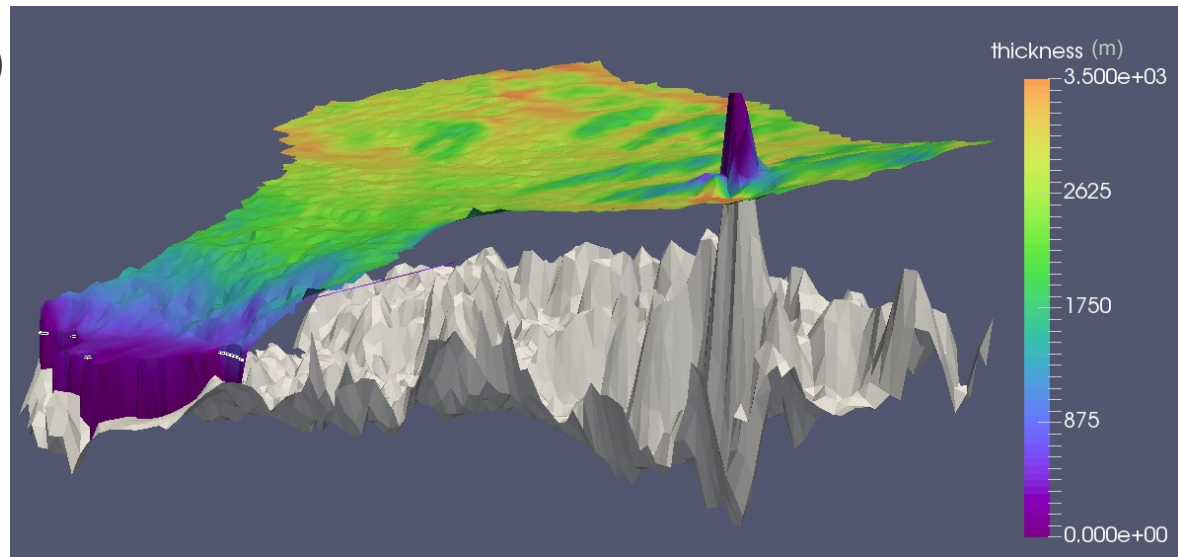
- El Nino/Southern Oscillation (2-7 yr)
- Southern Annular Mode (20-30 yr)
- Pacific Decadal Oscillation (15-25 yr, 50-70 yr)
- Atlantic Multidecadal Oscillation (50-80 yr)



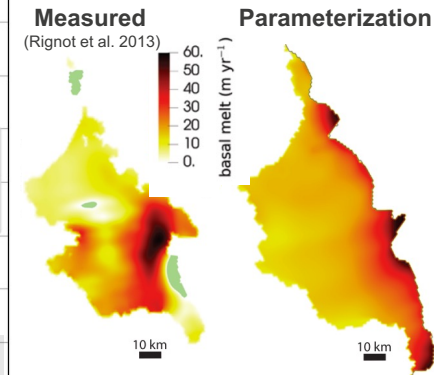
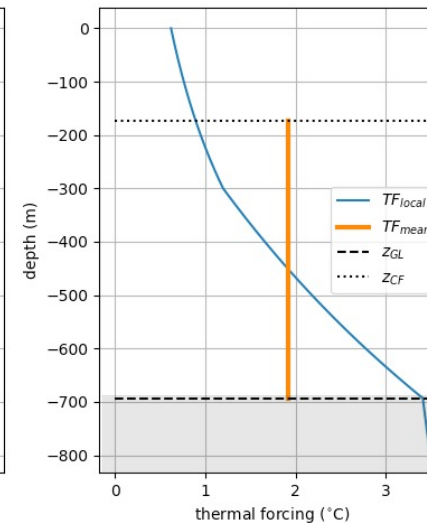
How might climate variability affect marine ice sheet stability?

Model setup

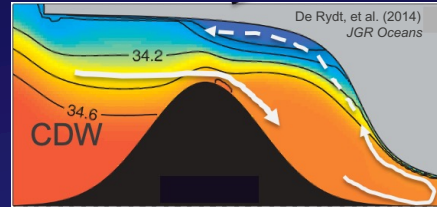
- MPAS-Albany Land Ice (MALI)
- 3d First-order momentum balance approx. (Blatter/Pattyn)
- Variable resolution regional mesh (1-8 km)
- Thickness, bed elevation from BEDMAP2
- Linear basal friction law
- Basal friction parameter optimized from InSAR surface velocity
- Fixed temperature field (pers. comm. Frank Pattyn)
- Calving front fixed in time
- SMB from RACMO2
- *Validated by observed grounding line flux transient*



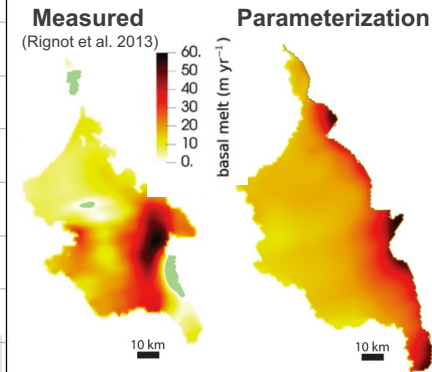
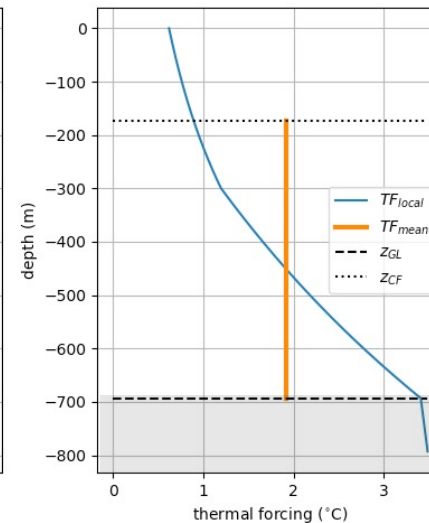
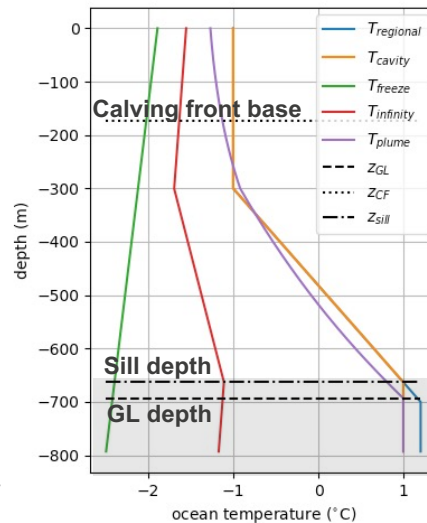
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Ice shelf basal melting parameterization



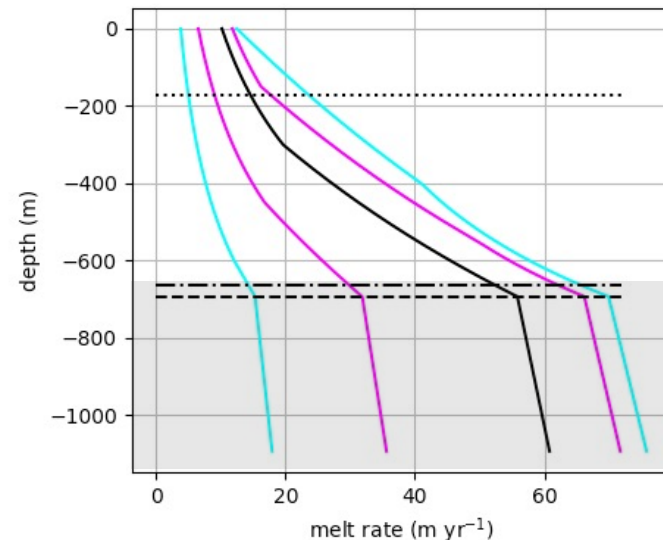
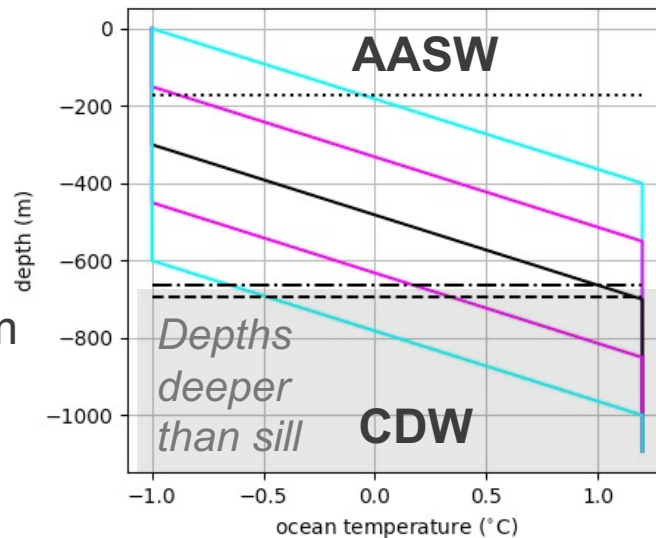
- $M = C TF_{local} TF_{cavity}$
- T_{cavity} : Mean ambient temperature
- T_{local} : Melt plume temperature profile based on ambient temperature at GL
- Inclusion of sill depth blocking deeper water



We add variability to depth relation to mimic changes in CDW depth

Sinusoidal variations:

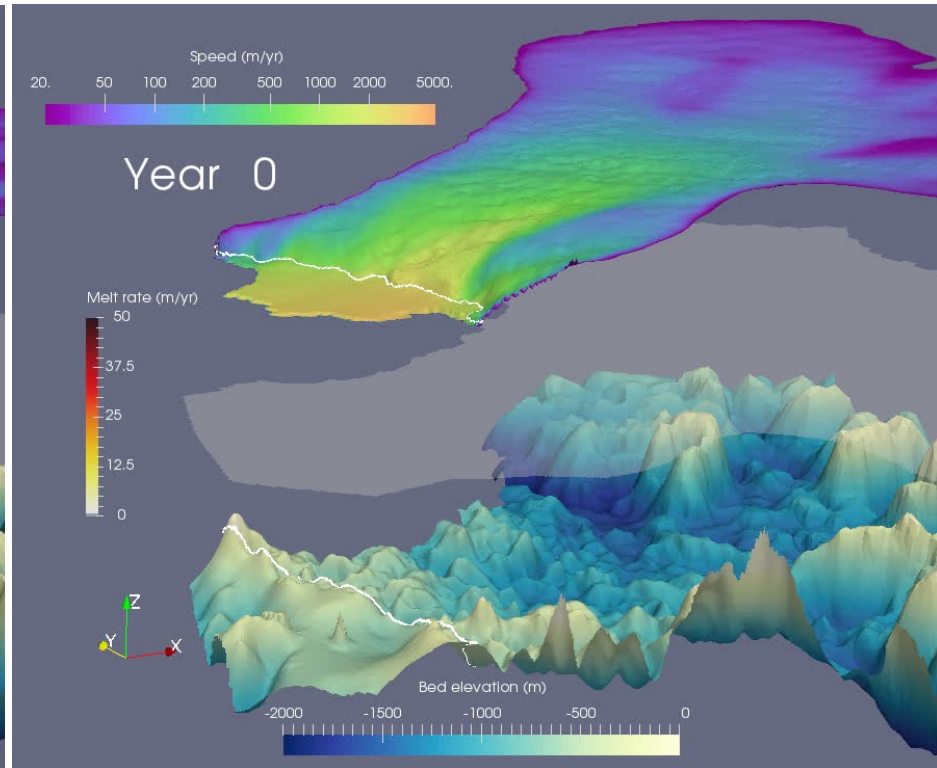
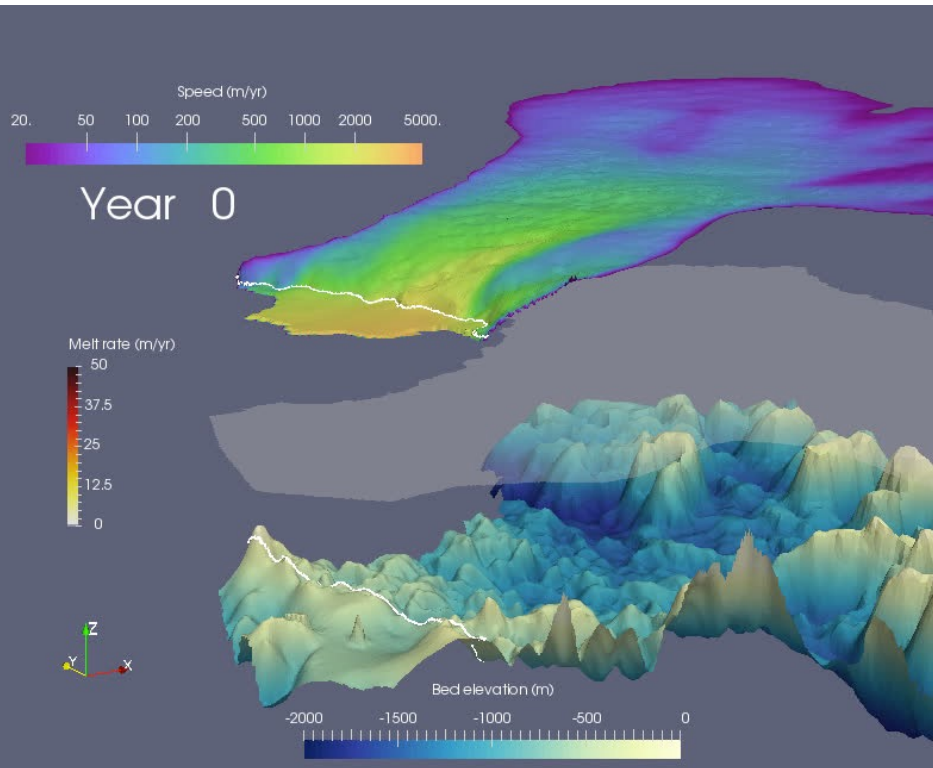
- amplitude: **150, 300 m**
- period: **5, 20, 70 yr**
- phase: $[0, 2\pi)$



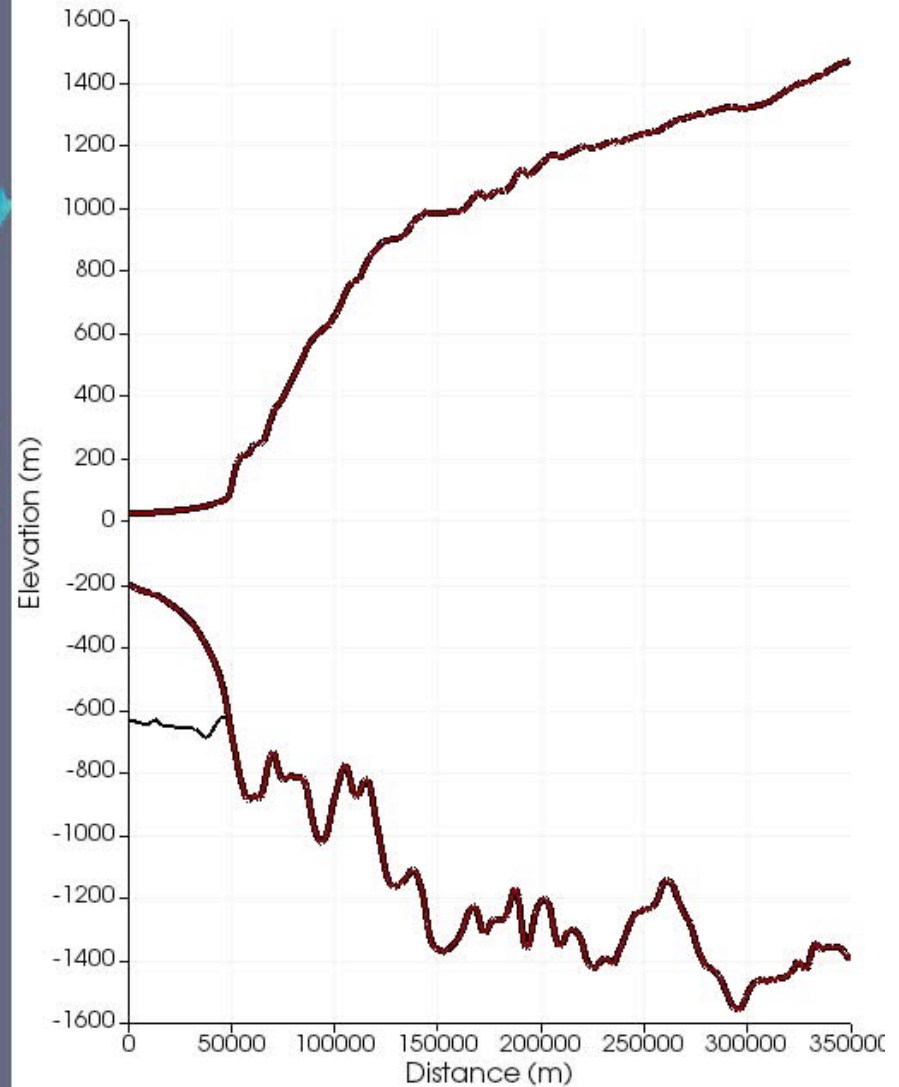
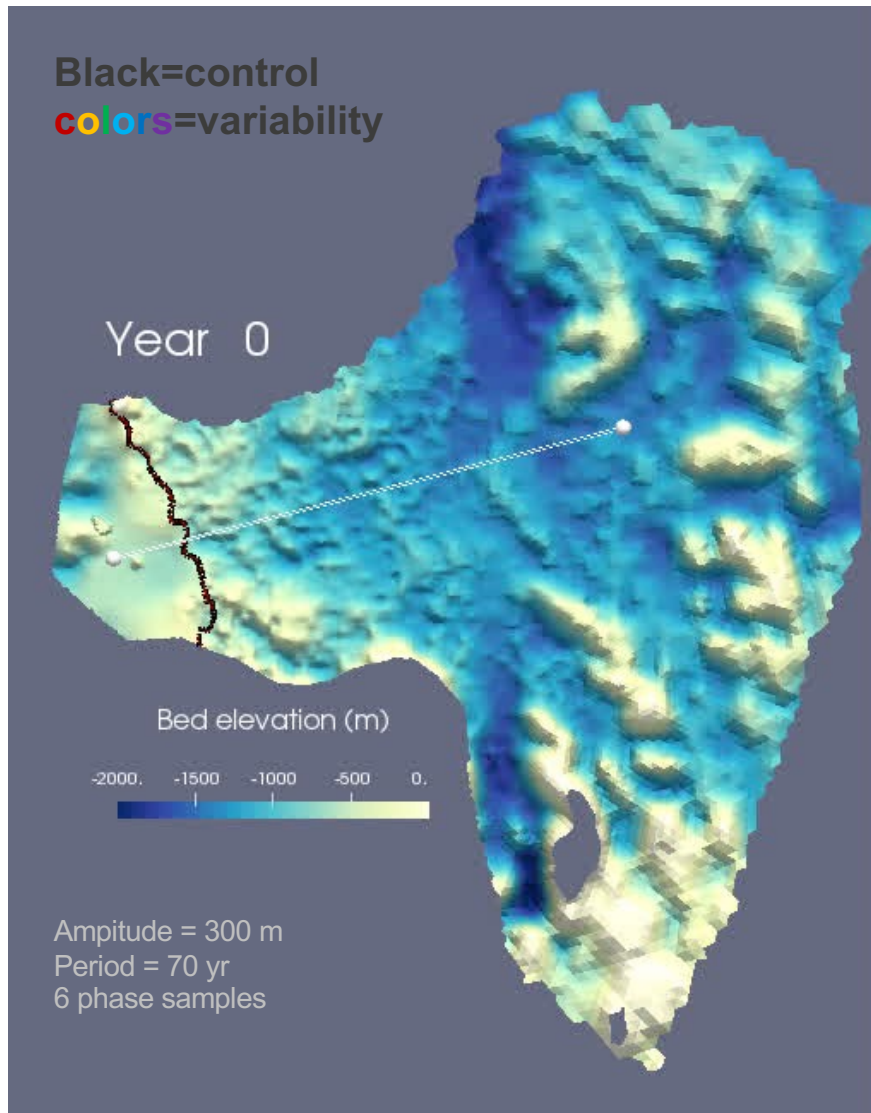
Results

Control

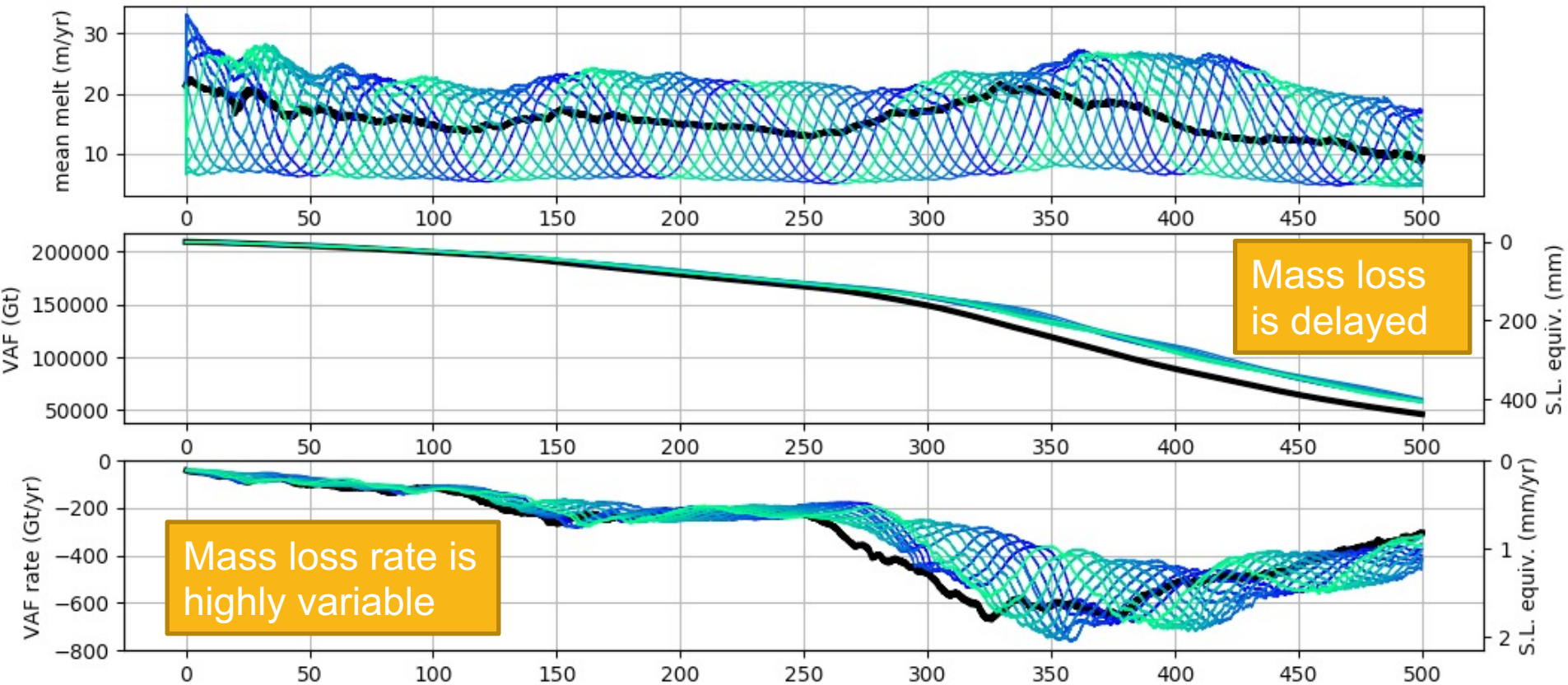
Amplitude=300m
Period=20 yr



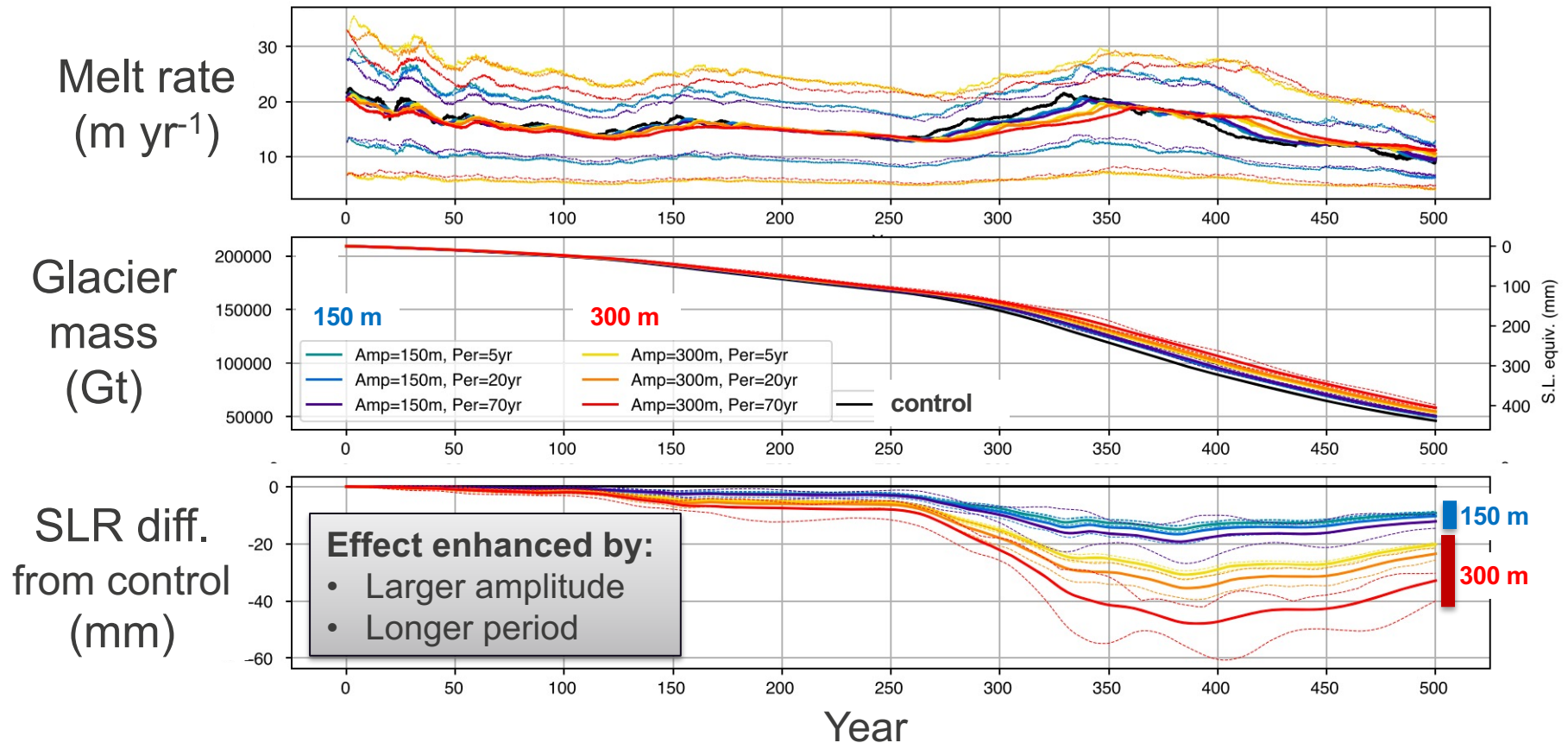
Results: Ocean variability introduces variability in glacier retreat



Results: Single ensemble (amplitude=300 m, period=70 yr)

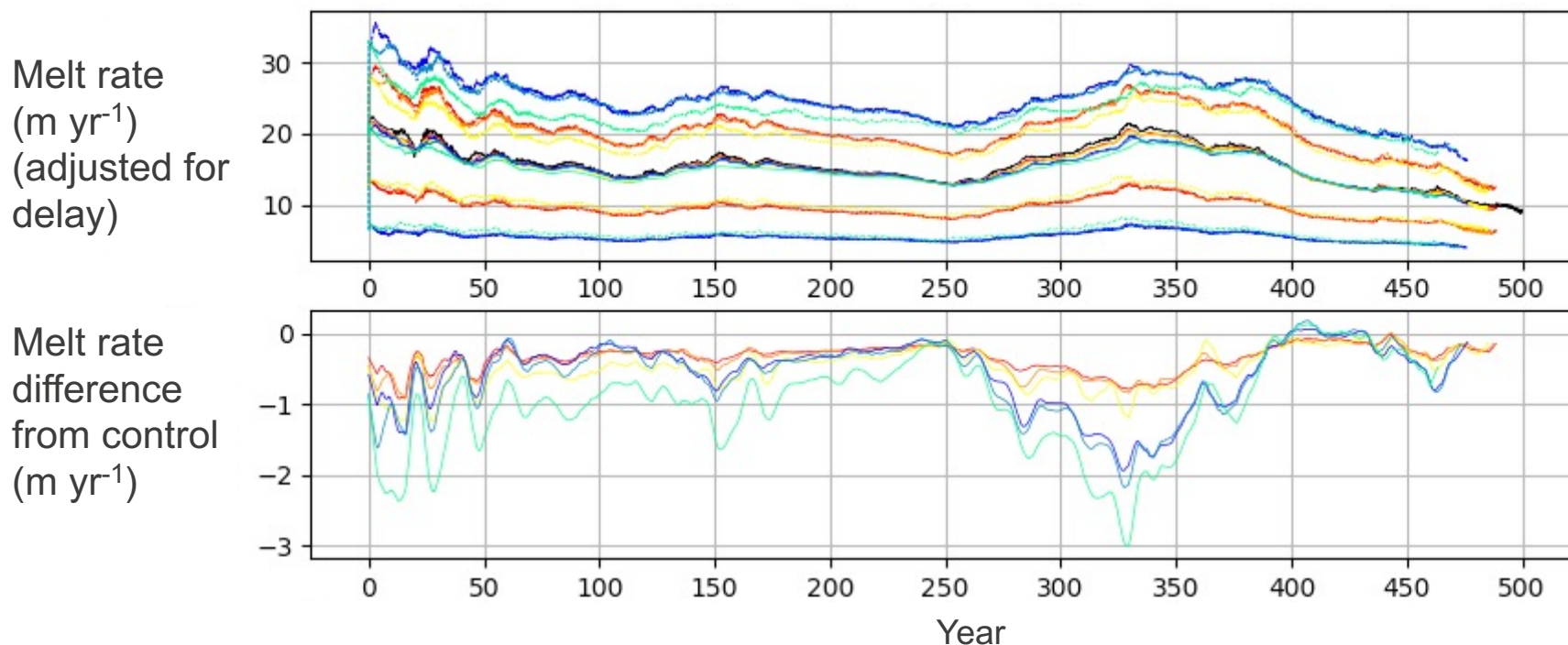


Results: All ensembles



Mechanisms for delay in mass loss

1. Asymmetric melt forcing – primary mechanism (~75% of delay)

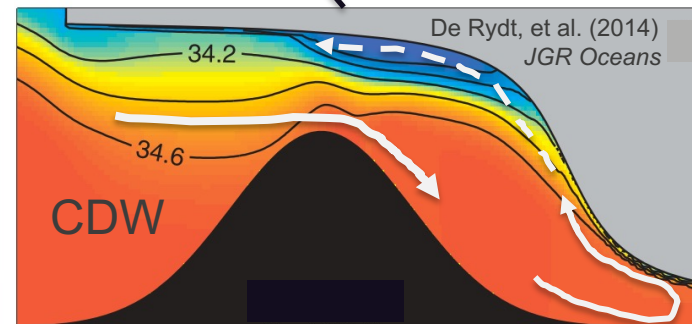
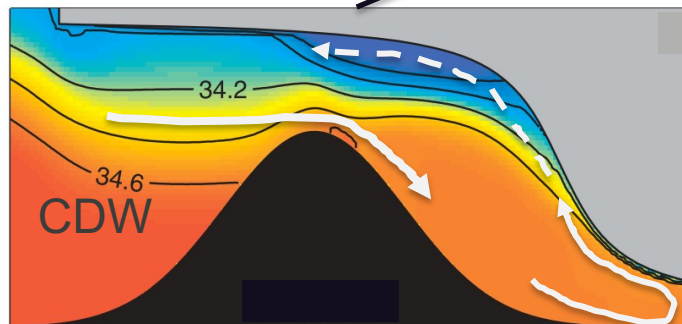
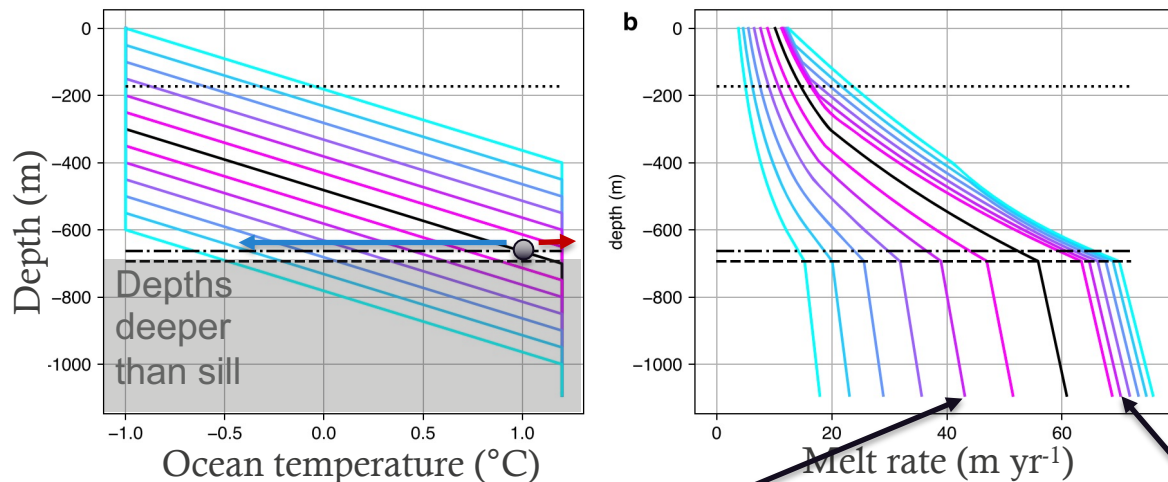


Mechanisms for delay in mass loss

1. Asymmetric melt forcing

Warm ocean cavity can't get much warmer:

- Bottom of thermocline near sill depth
- Deepening CDW → lower ocean temperature at GL
- Shoaling CDW → little change in ocean temperature at GL

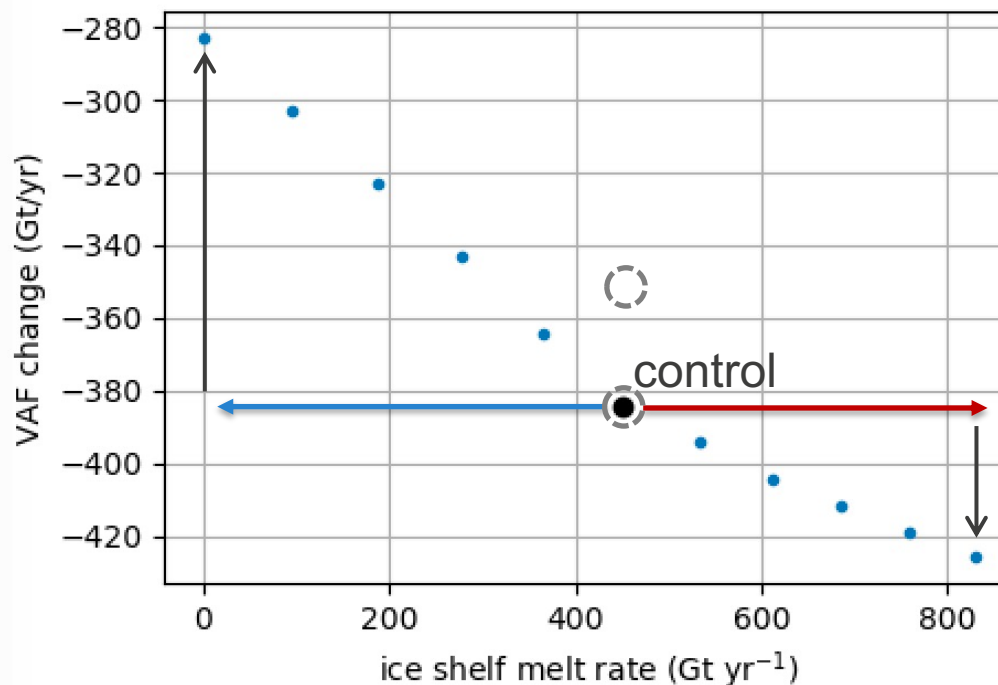


Mechanisms for delay in mass loss

2. Nonlinear ice dynamic response to ice shelf melting

– secondary mechanism (~25% of delay)

- Decreasing melt → large decrease in mass loss
- Increasing melt → small increase in mass loss



Conclusions

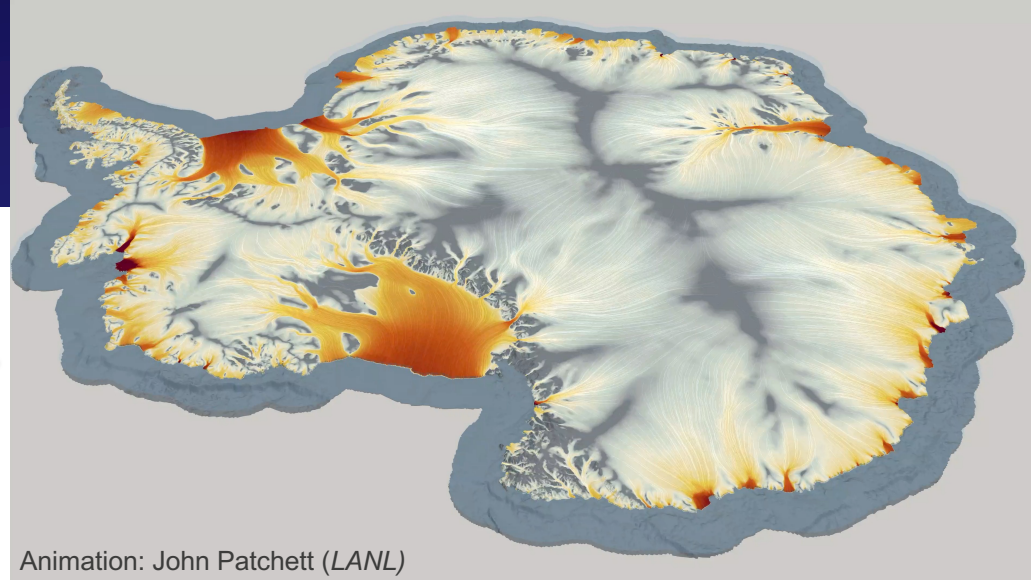
Ocean temperature variability affects grounding line evolution and glacier mass loss

- Variable runs always retreat *less* than steady runs
 - Consequence of local ocean density structure and bathymetry
- 10% *less* SLR for plausible large amplitude, long period variability after hundreds of years
- Effects small ($\sim 3\%$) for realistic (?) modes of variability
- Caveats: parameterized melt, simplistic variability, uncertain bed topography

Related work

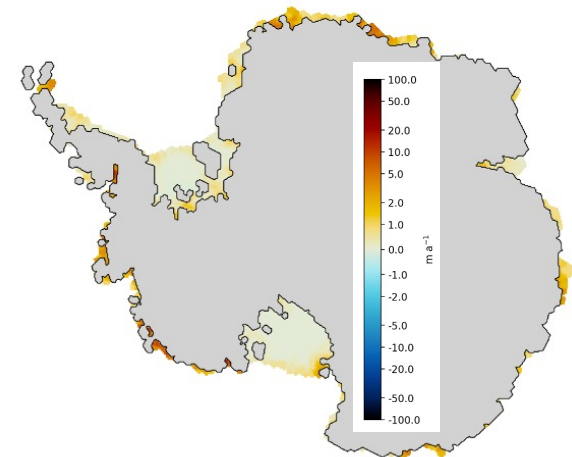
Ice Sheets

- MALI AIS & GIS simulations (ISMIP6 & beyond) →
- Improved ice sheet physics (calving, subglacial hydrology, GIA)



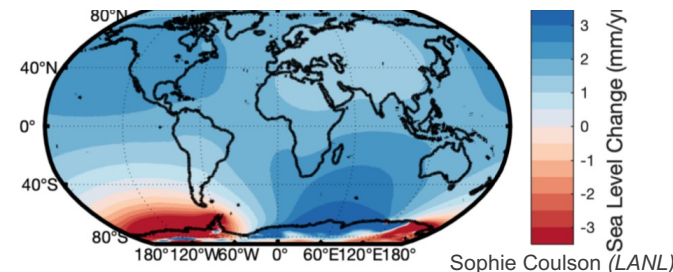
Climate

- Prognostic subshelf melt rates in E3SM →
- Coupling of MALI and MPAS-Ocean in E3SM



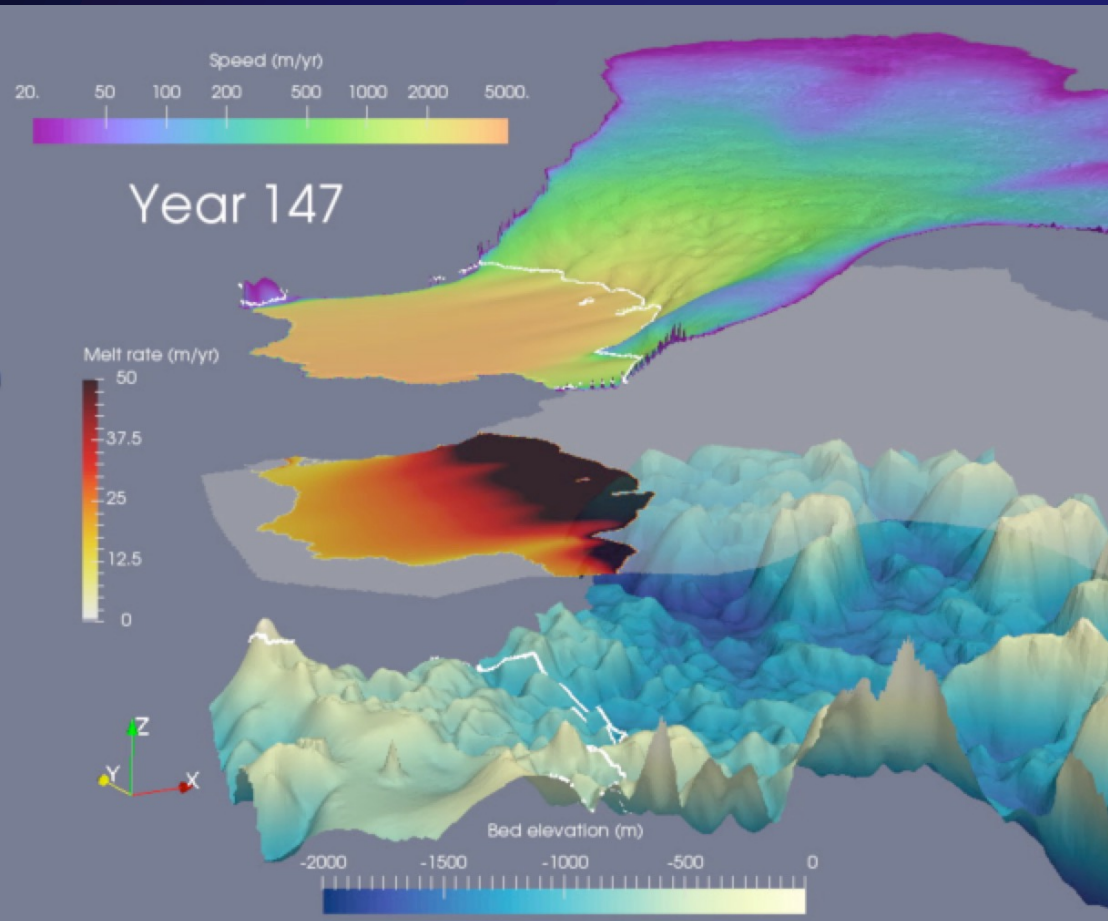
Sea Level

- Regional sea level projections from ice sheet, glacier, and ocean changes →



Sophie Coulson (LANL)

Questions?



Delivering science and technology
to protect our nation
and promote world stability

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Early Career Research Program
- National Energy Research Scientific Computing
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